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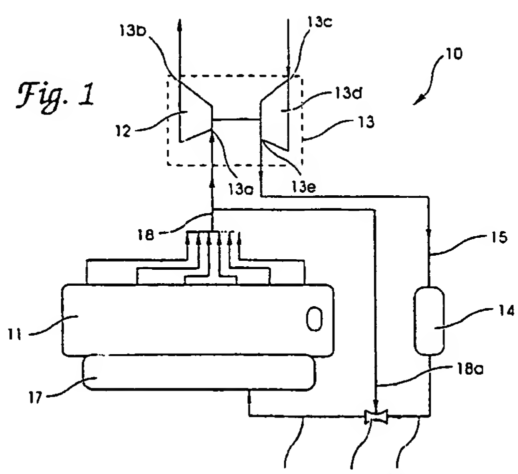
(54) Turbocharged diesel engines.

(57) A gas flow network in combination with a highly turbocharged diesel engine (11) for the blending of either EGR gas or blow-by gas from the crankcase vent with fresh charge air. In the diesel engine assembly which incorporates the flow network (10) for EGR gas, a venturi (19) is positioned between the intake manifold (17) and aftercooler (14) is connected to a flow line (16) carrying the EGR gas. In a related arrangement a control valve may be utilized to govern the availability of EGR. When the turbocharged diesel engine (11) assembly is configured with a flow path for blow-by gas, the venturi (19) is positioned between the intake manifold (17) and aftercooler (14) and is connected to a flow line (16) carrying blow-by gas. These systems utilise a low static pressure at the narrow throat of the venturi (19) so as to induce the flow of EGR gas or blow-by gas into the fresh charge air.

Fig. 1



EP 0 653 559 A1

BACKGROUND OF THE INVENTION

The present invention relates in general to the routing and flow path for recirculating exhaust gas and the routing and flow path for blow-by (crankcase vent) gas. More specifically the present invention relates to the use of venturi designs in the flow paths to introduce the particular gases into the intake manifold in a mix with fresh charge air from the turbocharger.

At the present time blow-by (crankcase vent) gas of medium and heavy duty diesel engines is typically vented to the atmosphere. However, it is expected that in the near future environmental/emissions legislation will mandate that this gas be recirculated into the fresh charge air. The expected legislation will likely be similar if not the same as what is now in effect for gasoline engines and light duty diesel engines.

In anticipation of such legislation, some thought must be given to where and how such blow-by gas can be integrated into the air/gas flow network. One option, routing the blow-by gas in front of the compressor of the turbocharger is not desirable due to fouling of the wheel and aftercooler by oily deposits and other particulate matter.

In one embodiment of the present invention a venturi is placed in the flow path downstream of the aftercooler so as to induce the flow of blow-by gas into the fresh charge air. The induced flow is created by having a low enough static pressure at the throat of the venturi. Several venturi designs are disclosed, each of which is suitable for the present invention.

A related gas flow arrangement which is applicable to diesel engine design is exhaust gas recirculation or EGR as it is abbreviated. A variety of exhaust gas recirculation systems are known to exist and a representative sampling of such systems is provided by the listing of United States patent references which are set forth hereinafter.

One application proposed for EGR, as perceived by the present inventors, is to use EGR as a means of reducing NO_x in medium and heavy duty turbocharged diesel engines. For such engines EGR should be introduced at various speed and load conditions to be effective in NO_x reduction due to the type of transient testing required by EPA and CARB.

In these engines the intake manifold pressure (boost) is typically higher than exhaust pressure in front of the turbine of the turbocharger. One choice would be to route the exhaust gas to the inlet of the compressor of the turbocharger. However, this is not a good practice due to the fouling of the compressor wheel and possibly the aftercooler due to particulate in the exhaust gas. Also, the compressor wheel which is typically made of aluminum cannot tolerate the high temperature of the incoming mixture of fresh air and exhaust gas due to the very high temperature of the compressed mixture at the point of leaving the wheel.

In a related embodiment of the present invention a venturi is placed in the fresh charge air flow line between the compressor and aftercooler and is connected to an exhaust gas flow line whose input side is connected between the exhaust manifold and the turbine. Static pressure at the throat of the venturi is sufficiently low so as to induce the flow of exhaust gas into the flow of fresh charge air.

With regard to the various embodiments of the present invention, the following list of U.S. patent references is believed to provide a representative sampling of the types of flow paths and flow arrangements which have been conceived of in order to deal blow-by gas and recirculating exhaust gas.

Patent No.	Patentee	Date Issued
3,925,989	Pustelnik	Dec. 16, 1975
4,034,028	Tsoi-Hei Ma	July 5, 1977
4,206,606	Yamada	Jun. 10, 1980
4,363,310	Thurston	Dec. 14, 1982
4,462,379	Tsuge et al.	Jul. 31, 1984
4,478,199	Narasaka et al.	Oct. 23, 1984
4,479,478	Arnaud	Oct. 30, 1984
4,501,234	Toki et al.	Feb. 26, 1985
4,669,442	Nakamura et al.	Jun. 2, 1987
4,773,379	Hashimoto et al.	Sep. 27, 1988
4,924,668	Panten et al.	May 15, 1990
5,061,406	Cheng	Oct. 29, 1991
5,094,218	Everingham et al.	Mar. 10, 1992

While each of the foregoing references describe certain flow paths and flow arrangements, none are believed to include all of the novel features of the present invention.

SUMMARY OF THE INVENTION

A combination of a turbocharged diesel engine assembly and a venturi for blending outlet gas flow from the diesel engine with fresh charge air according to one embodiment of the present invention comprises a diesel engine, a turbocharger, a gas flow outlet from the diesel engine and a fresh charge air flow path from the turbocharger to the diesel engine so as to deliver fresh charge air from the turbocharger to the diesel engine and a venturi placed in the fresh charge air flow path after the turbocharger and being connected in flow communication with the gas flow outlet whereby gas flow exiting from the gas flow outlet is blended with fresh charge air due to a low static pressure created by the venturi.

One object of the present invention is to provide an improved turbocharged diesel engine assembly which includes a venturi for blending outlet gas flow and fresh charge air.

Related objects and advantages of the present invention will be apparent from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a turbocharged diesel engine assembly including a venturi in the air flow path according to a typical embodiment of the present invention.

FIG. 2 is a schematic illustration of a turbocharged diesel engine assembly including a venturi in the air flow path according to a typical embodiment of the present invention.

FIG. 3 is a diagrammatic illustration of an alternative configuration for placement of the FIG. 2 venturi in the flow path.

FIG. 4 is a diagrammatic illustration of a flow tube and flow line arrangement which results in a venturi effect and which is suitable for use in either the FIG. 1 or FIG. 2 assemblies.

FIG. 5 is a schematic illustration of a turbocharged diesel engine assembly with a venturi in the air flow path according to a typical embodiment of the present invention.

FIG. 6 is a diagrammatic illustration of a control valve which is suitable for use in the flow path of the FIG. 5 assembly.

FIG. 7 is a diagrammatic illustration of a control valve design which is suitable for use in the FIG. 5 assembly.

FIG. 8 is a diagrammatic illustration of a variable flow rate venturi which may be used with any of the FIG.

1, FIG. 2 or FIG. 5 assemblies.

FIG. 9 is a diagrammatic illustration of a variable throat area venturi which is suitable for use with any of the FIG. 1, FIG. 2 or FIG. 5 assemblies.

DESCRIPTION OF THE PREFERRED EMBODIMENT

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiment illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated device, and such further applications of the principles of the invention as illustrated therein being contemplated as would normally occur to one skilled in the art to which the invention relates.

Referring to FIG. 1 there is illustrated a schematic representation of an air/exhaust flow network 10 for a highly turbocharged diesel engine 11. In this schematic representation the exhaust gas from the cylinders (exhaust manifold) is directed to turbine 12 of the turbocharger 13. In the context of this description and for the purposes of this disclosure, the illustration of FIG. 1 is actually a turbocharged diesel engine assembly which includes the actual engine 11 as well as separate turbocharger 13, aftercooler 14, various flow lines and components.

Turbocharger 13 is of a conventional construction and operation. Its structure includes exhaust intake 13a, exhaust outlet 13b, air intake 13c, compressor 13d and compressed air outlet 13e. Flow line 15 routes compressed air (fresh charge air) to the aftercooler 14 and from there via flow line 16 to the intake manifold 17 of engine 11. Flow 18 connects the exhaust manifold to the turbine and flow line 18a is connected to flow line 18 as illustrated. Disposed in flow line 16 is venturi 19 and flow line 18a is designed to deliver recirculating engine gas (EGR) to venturi 19 by means of the low static pressure of venturi 19. Venturi 19 may be configured with a fixed or variable throat area and it creates a low enough static pressure so as to induce the flow of EGR gas from flow line 18a into the flow of fresh charge air from aftercooler 14.

Referring to FIG. 2 there is illustrated a schematic representation of an air/exhaust flow network 20 for a highly turbocharged diesel engine 21. In this schematic representation, similar to the FIG. 1 system, the exhaust gas from the cylinders (exhaust manifold) are directed to turbine 22 of turbocharger 23. In the context of this description the illustration of FIG. 2 is actually a turbocharged diesel engine assembly which includes the actual engine as well as a separate turbocharger and other flow lines and components.

Turbocharger 23 is of a conventional construction and operation. Its structure includes exhaust intake 24, exhaust outlet 25, air intake 26, compressor 27 and compressed air outlet 28. Flow line 32 routes the compressed air (fresh charge air) to the aftercooler 33 and from there via flow line 34 to the intake manifold 35 of engine 21.

The crankcase vent 39 delivers blow-by gas via flow line 40 to venturi 41 which is disposed within flow line 34. Venturi 41 may be configured with a fixed or variable throat area and it creates a low enough static pressure so as to induce the flow of blow-by gas from flow line 40 into the flow of fresh charge air from aftercooler 33.

Referring to FIG. 3 one venturi design suitable for the present invention is diagrammatically illustrated. Venturi 44 which is suitable for use as either venturi 19 or venturi 41 is disposed in a branch line 45 which splits off of flow line 34 (or flow line 16 in FIG. 1). Branch line 45 which incorporates the venturi 44 then rejoins flow line 34 (16) downstream of the venturi 44.

Using the FIG. 2 system as the reference system for FIGS. 3 and 4, flow line 40 which delivers the blow-by gas to the low pressure throat of the venturi 44 is shown as intersecting the sidewall of venturi 44. In this embodiment only a smaller portion of the entire fresh charge air in flow line 34 is split into branch line 45 and flows through venturi 44. Butterfly valve 46 disposed in flow line 34 is used to control the amount of gas flowing to venturi 44. By the arrangement of FIG. 3 flow losses are reduced and there is still a low enough static pressure at the venturi throat to induce in flow of blow-by gas (FIG. 2) or EGR gas (FIG. 1).

Referring to FIG. 4 another design suitable for the present invention (including the FIG. 1 and FIG. 2 systems) is diagrammatically illustrated. The arrangement of FIG. 4 represents a relatively simple way to introduce EGR gas into the flow of fresh charge air in flow line 16 (FIG. 1) or blow-by gas into the flow of fresh charge air in flow line 34 (FIG. 2). By means of a small pipe 50 inserted into flow line 34 and directed in a downstream direction, blow-by gas is drawn into the flow of fresh charge air. While pipe 50 acts as a type of ejector, flow is still the result of pressure differences. The pressure drop which is part of the flow of the fresh charge air creates enough of a pressure drop relative to the pressure in pipe 50 for a suction action to occur and for the blow-by gas to be drawn from the small pipe 50 into flow line 34.

Referring to FIG. 5 there is illustrated a schematic representation of an alternative EGR system 55 for a

highly turbocharged diesel engine 56 according to the present invention. EGR system 55 is configured in several respects in a manner similar to flow networks 10 and 20. The most notable differences are the positioning of the venturi 57 upstream of the aftercooler 58 and the addition of flow line 59, filter 60 and control valve 61. The cylinder exhaust from engine 56 (exhaust manifold) flows into the turbine 66 of turbocharger 67. Flow line 59 is a branch line off of flow line 69 and intersects flow line 69 upstream of the turbocharger 67. Flow line 59 routes exhaust gas first through filter 60 and then through control valve 61 and finally to venturi 57. Although flow line 59 is in fact arranged in three sections, the same reference number has been used to indicate a single flow path from flow line 69 to venturi 57. Flow line 70 from compressor 71 carries compressed air (fresh charge air) to venturi 57. The output side of venturi 57 flows into aftercooler 58 and from there to intake manifold 72.

By using a venturi 57 (with either a fixed or variable throat area) downstream of the compressor 71, static pressure at the throat can be sufficiently low to induce the flow of exhaust gas. Venturi 57 may be made of aluminum or other low cost material because it is not subject to high mechanical loading unlike the compressor wheel. By using a small filter 60 which can be either self-regenerating at high loads or electrically regenerated, fouling of the aftercooler 58 can be eliminated. In the case of fairly clean exhaust gas, the filter 60 can be omitted. This system also allows for only one heat exchanger of the intake air instead of having another small heat exchanger in the EGR loop. Cooled EGR helps maintain a higher air/fuel ratio so that with the introduction of exhaust gas into the fresh charge air there is no increase or only a very small increase in particulate, thus resulting in better NO_x--particulate trade-off than without cooled EGR.

In order to control when EGR is introduced into the fresh charge air there is a control valve 61. This valve can be solenoid operated and controlled by the central electronic control unit (ECU), thus providing EGR as a function of speed and load. If the engine does not have an electronic fuel injection system, it would be quite expensive to have an ECU and appropriate sensors just for control of EGR. In this case by providing a simple spring biased control valve (see FIG. 5) the exhaust gas flows into the fresh charge air, via venturi 57, at and above a predetermined pressure in the exhaust manifold.

Referring more specifically to the control valve 75 of FIG. 6, a closing flap or plate 76 is placed at an angle and hinged within the flow line 77. The flow line 77 which receives control valve 75 is effectively the same as flow line 59. As such flow line 77 extends from the exhaust manifold of engine 56 to venturi 57. Plate 76 is spring biased by means of spring 78 and piston 79. Whenever the line pressure of the exhaust gas from the exhaust manifold is sufficient to overcome the predetermined spring force, exhaust gas is allowed to flow into the fresh charge air from the turbocharger 67 via the venturi 57. In effect a predetermined pressure in the exhaust manifold is selected as the threshhold for the introduction of exhaust gas into the venturi and the spring bias is set accordingly.

As stated, the venturi style of venturi 57 as used in system 55 may have a fixed or variable throat area and otherwise be of conventional construction as would be known to a person of ordinary skill in the art. It is also an option to replace venturi 57 with either of the venturi styles or arrangements of FIGS. 3 and 4. While the small pipe arrangement of FIG. 4 is not shaped as a narrow throated venturi conduit or nozzle, there is a pressure difference which influences the flow of exhaust (or blow-by) gas into the primary flow of fresh charge air.

Referring to FIG. 7 an alternative embodiment of a suitable control valve is illustrated. Control valve 85 is positioned above flow line 86 (same as flow lines 59 and 77) which extends from the exhaust manifold of engine 56 to venturi 57. An enclosed spring chamber 87 receives a bias spring 88 which acts on a diaphragm piston 89 having as a piston arm a connected flow-blocking plate 90 that extends into and across flow line 86. Plate 90 is sized and shaped to block the flow of exhaust gas unless a sufficient boost pressure is seen by diaphragm 91. By means of conduit 92 the intake manifold boost pressure acts on diaphragm 91.

Similar in concept to control valve 75, the spring biasing force is predetermined at a level which correlates to a predetermined boost pressure. When that pressure is exceeded the spring force is overcome and the diaphragm pushed upwardly, lifting plate 90 which in turn enables some flow through flow line 86. The greater the boost pressure over the threshhold level, the more compression of bias spring 88 and the more flow clearance which is provided in flow line 86.

As already briefly mentioned exhaust gas recirculation (EGR) is proposed as a means of reducing NO_x in medium and heavy duty turbocharged diesel engines. The exhaust gas will flow from the exhaust side to intake side through a simple tube if the exhaust side pressure is greater than the intake side pressure. However, in many engine operating conditions the intake side pressure is either about the same as the exhaust-side pressure or greater than the exhaust-side pressure. The intake side static pressure can be reduced by accelerating the intake-side flow through a venturi. Connecting the EGR tube to the venturi throat will increase the pressure differential from the exhaust to intake side which will enhance the EGR flow rates and increase the number of engine operating conditions where EGR is possible. This is basically the technical foundation or theory as embodied by systems 10 and 55 and the designs of venturis 19 and 57 (and the venturi design variations of

FIGS. 3 and 4) and control valves 75 and 85.

Referring now to FIGS. 8 and 9 two further venturi designs which are suitable for use with the present invention are illustrated. Each of these designs provide control over the EGR flow rate by controlling the pressure at the venturi throat.

Referring first to FIG. 8, venturi 95 is a variable mass flow or flow rate venturi. Venturi 95 is to be positioned similar to venturi 57 (see FIG. 5) downstream from the compressor and upstream from the aftercooler. Inlet 96 receives the fresh charge air from the compressor and this incoming flow is directed by a controllable diverter valve 97. Flow chamber 98 is separated by partition 99 into a by-pass path 100 and a venturi path 101. When the closing flap 102 of diverter valve 97 is moved all the way to the right (broken line position) the venturi path 101 is completely closed off from the incoming fresh charge air which flows through the by-pass path 100 to the aftercooler without the introduction of any EGR.

When closing flap 102 is positioned all the way to the left so as to close off the by-pass path 100, the venturi path 101 is opened. As fresh charge air flows through the venturi path, the narrow throat 105 creates a venturi effect on the EGR which is present within flow line 106 coming from the exhaust manifold.

As will be appreciated, the controllable diverter valve 97 is capable of being positioned at virtually any point in between the two extremes of all of the way to the left or all the way to the right. When the closing flap 102 of the diverter valve is positioned between the end point extremes it will adjust or proportion the flow between the two flow paths 100 and 101. The static pressure at the venturi throat and thus the differential pressure is set by controlling the mass flow through the venturi flow path. The throat section of the venturi is sized to provide controllable EGR over the entire engine map.

Referring to FIG. 9 a variable area of venturi design is illustrated. Venturi arrangement 110 is positioned in a flow line 111 with an intake side 112 and an exit flow side 113. The EGR flow line 114 intersects the flow line 111 as illustrated. The point of intersection is at a narrowed portion 115 of flow line 111; the narrowing being achieved by the placement of a narrowing sleeve in the flow line 111. The remainder of venturi arrangement 110 includes guide rings 118, struts 119, actuator 120 and centerbody 121.

Centerbody 121 which is aerodynamically smooth is positioned within the slight area reduction section (portion 115) and is moveable axially relative to the area reduction section. The static pressure at the venturi throat is controlled by changing the venturi area via the centerbody position. The centerbody 121 is held by struts 119 to guide rings 118 which keep the centerbody in the center of the tube. The rear guide ring is used as a shut-off valve. The controlling actuator is located in the clean, up stream air.

The venturi arrangements of FIG. 8 and 9 are suitable for use as the venturi of the FIG. 1 flow network 10 or the FIG. 2 flow network 20 or the FIG. 5 flow system 55.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiment has been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

Claims

1. In combination:

    a turbocharged diesel engine assembly including a diesel engine, a turbocharger, an engine gas flow line from said diesel engine for routing engine gas out of said diesel engine, and a fresh charge air flow line from said turbocharger to said diesel engine so as to deliver fresh charge air from said turbocharger to said diesel engine; and

    a venturi placed in said fresh charge air flow line and being connected in flow communication with said engine gas flow line whereby engine gas exiting from said diesel engine and flowing through said engine gas flow line is blended with fresh charge air due to a low static pressure created by said venturi.

2. A combination according to claim 1 wherein said turbocharged diesel engine assembly includes an aftercooler in said fresh charge air flow line.

3. A combination according to claim 2 wherein said venturi is placed downstream of said aftercooler between said aftercooler and said engine.

4. A combination according to claim 2 wherein said venturi is placed upstream of said aftercooler between said aftercooler and said turbocharger.

5. A combination according to claim 4 wherein said turbocharged diesel engine assembly includes a filter in said engine gas flow line upstream of said venturi.

6. A combination according to claim 4 or claim 5 wherein said turbocharged diesel engine assembly includes a control valve in said engine gas flow line upstream of said venturi.

7. A combination according to claim 6 when appended to claim 4 wherein said control valve is solenoid operated and provides engine gas to said venturi as a fuction of speed and load of said engine.

8. A combination according to any one of claims 1, 3 and 7 wherein said engine gas is, EGR gas, or when appended to claim 3, wherein said engine gas is blow-by gas.

9. A combination according to claim 8 when appended to claim 1 which further includes a control valve in said engine gas flow line to control the delivery of EGR gas as a function of engine speed and load.

10. A combination according to claim 9 wherein said control valve is designed with a spring-biased closing member disposed in said engine gas flow line which member opens in response to EGR gas pressure which is sufficient to overcome any opposing spring-bias force.

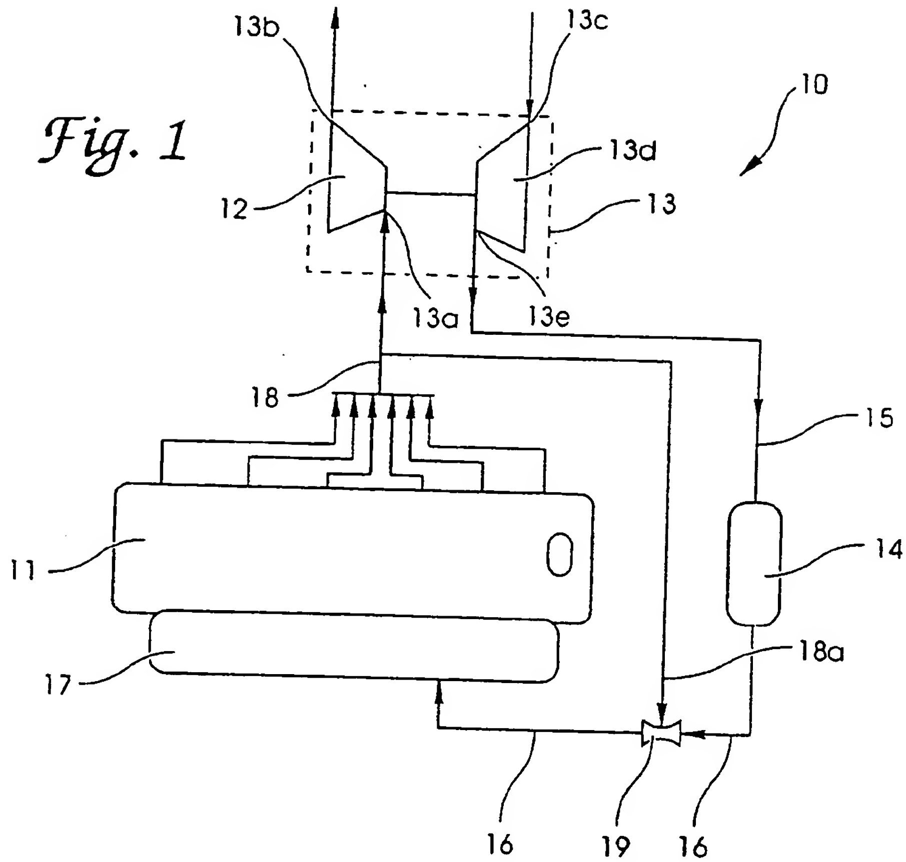

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Fig. 1

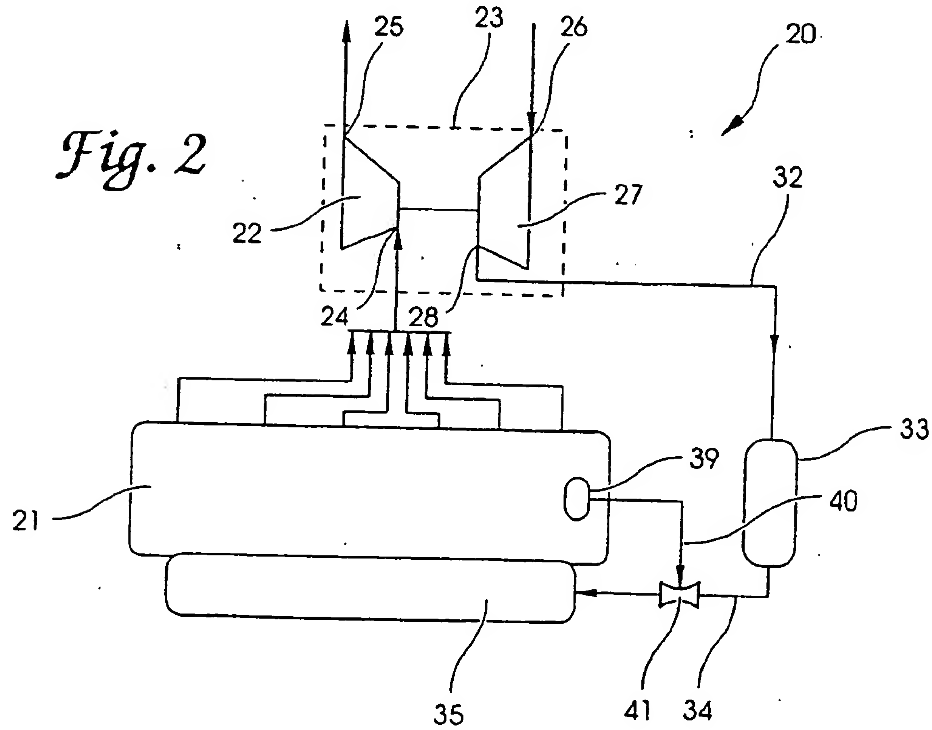
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Fig. 2

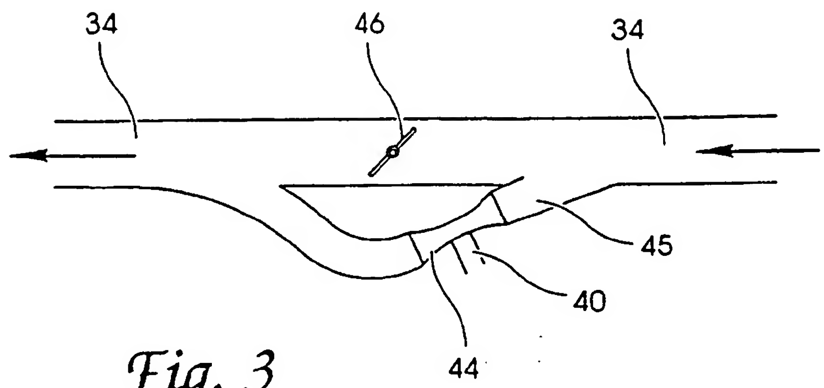

Fig. 3

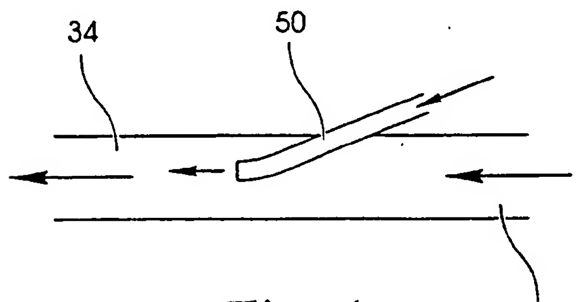

Fig. 4

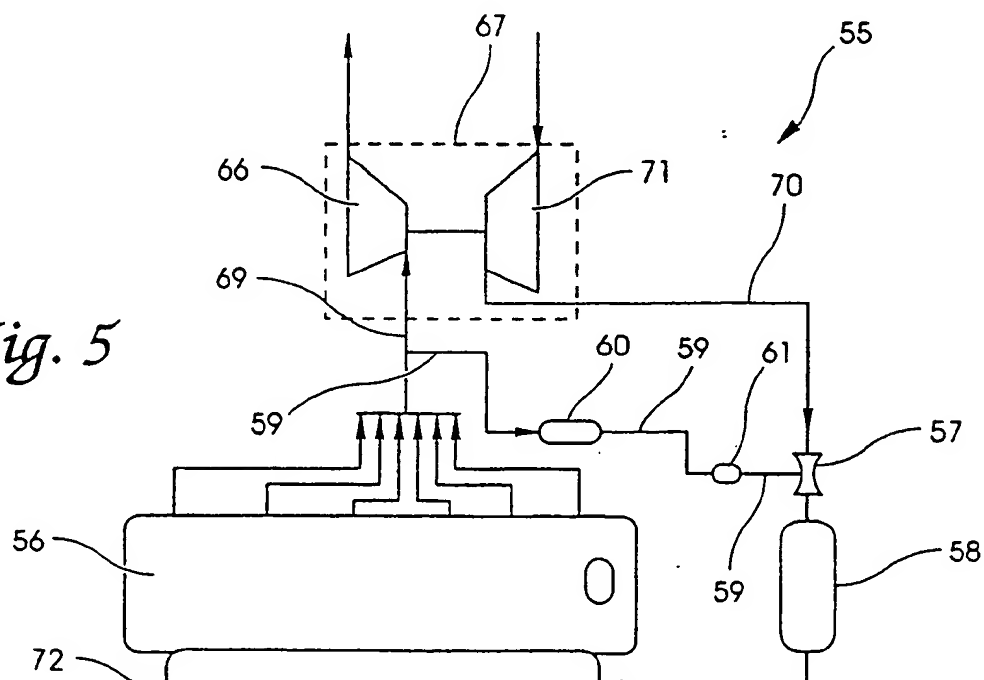

Fig. 5

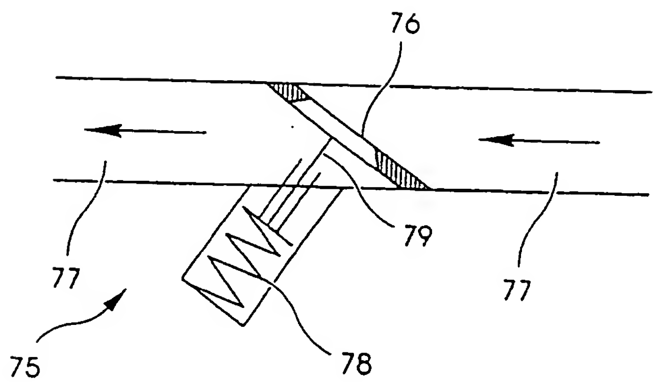

Fig. 6

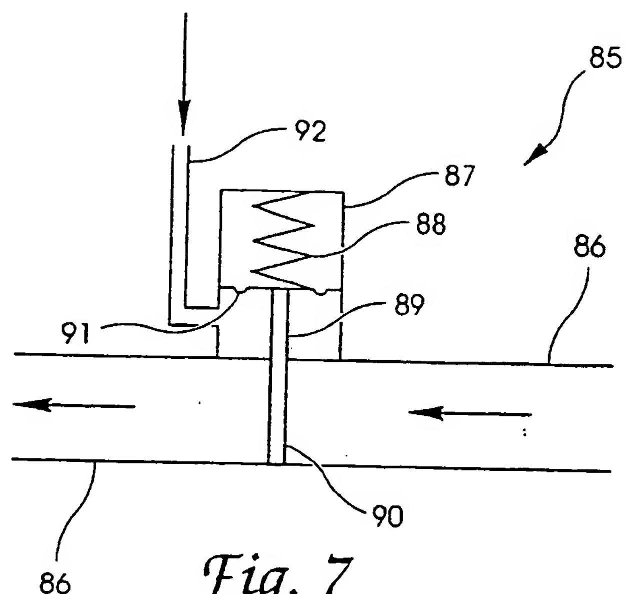

Fig. 7

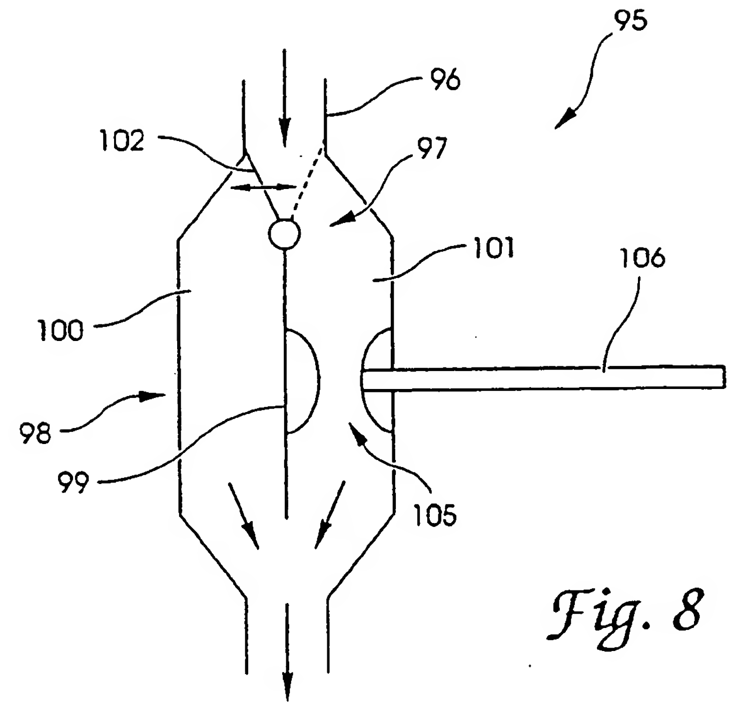
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Fig. 8

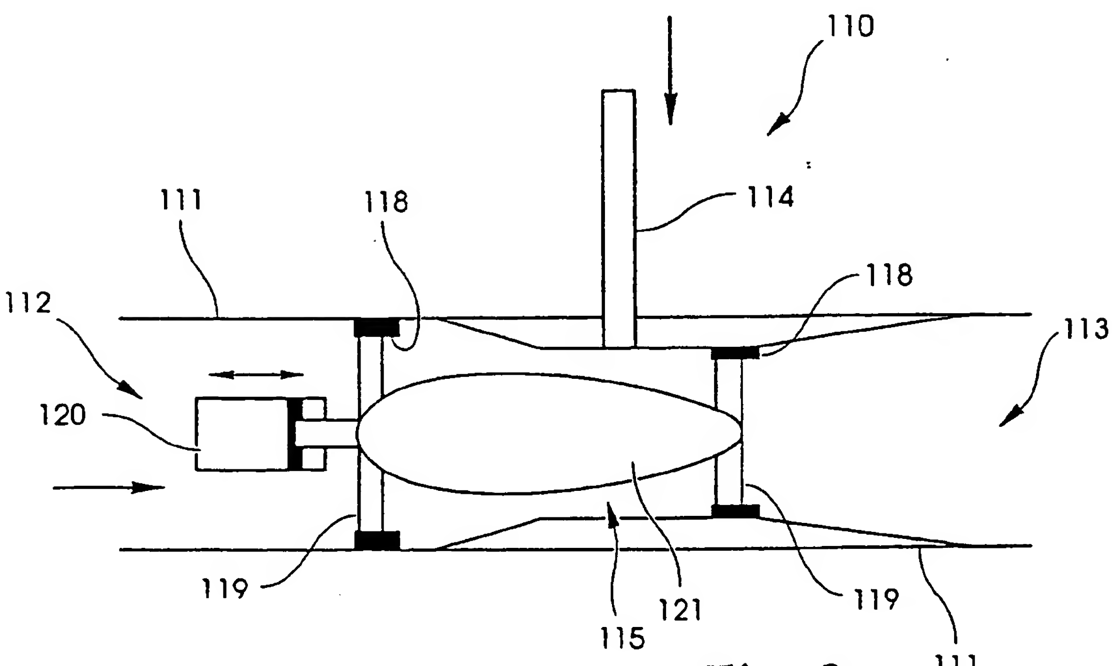
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Fig. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 8269

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP-A-0 080 327 (DRESSER INDUSTRIES INC.) * the whole document * ---	1-3,8,9 4-7,10	F02M25/07
X,P	US-A-5 333 456 (BOLLINGER) * the whole document * ---	1	
Y	PATENT ABSTRACTS OF JAPAN vol. 16, no. 343 (M-1285) 24 July 1992 & JP-A-04 103 867 (NISSAN MOTOR CO LTD) 6 April 1992 * abstract * ---	4-7	
X	DE-A-40 38 918 (DR.ING.H.C.F. PORSCHE) * column 5, line 42 - line 46; figures 1,3 * ---	1,8	
Y	GB-A-2 250 801 (PIERBURG GMBH) * abstract; figure 1 * ---	10	
A	DE-A-38 31 080 (VOLKSWAGEN AG) * figure * ---	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	FR-A-2 271 394 (ETAT FRANÇAIS) * figures * -----	1	F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 January 1995	Alconchel y Ungria,J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons

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EPO FORM 1503 03.82 (P04C01)